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FLORA OF NEEDHAM, MASSACHUSETTS—100 YEARS OF FLORISTIC CHANGE

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ABSTRACT. A floristic survey of Needham, Mass. was undertaken in 2000–2002 to compare the floristic diversity of this suburban community with a checklist of the flora compiled in 1885 by a local naturalist and to identify patterns and potential causes of change in floristic biodiversity. I found a modern flora of 628 species, of which 32% are introduced. Although the total number of species remained fairly constant (691 species were present in 1885), 43.5% of the native species, including 73 genera and 12 families, have been extirpated. The largest changes in the diversity of native species occurred in the Orchidaceae, with the loss of 85% of the species, and the ferns and other cryptogamic groups, with the loss of 50% of the species, including all taxa in the Ophioglossaceae. Of the extant species, 43% are restricted to one or two sites, and are considered at risk of extirpation. The change in biodiversity appears most closely correlated with the loss of open pasture habitats as a result of both development and succession to shrub or tree-dominated communities.

Key Words: Massachusetts, flora, biodiversity, species loss, invasive species, orchids, ferns

This study was undertaken to explore changes in floristic biological diversity in a small suburban Massachusetts town during the 20th century. Rather than a comprehensive flora of Needham, Massachusetts, this study contrasts two snapshots in time: 1880–1885 and 2000–2002. The study is intended to provide data from which to estimate the effects of development and vegetation change on floristic biodiversity. It complements other recent studies (Bertin 2000; Bertin 2003; Drayton and Primack 1996; Holland and Sorrie 1989; Robinson et al. 1994) that have examined floristic change in New England and New York.

The flora of the late 19th century is documented in an unpublished handwritten manuscript found in the New England Botanical Club archives, "A list of the Manual Plants That I have Collected In Needham," December 1885, by T. O. Fuller. Fuller's herbarium (Day 1901) was one of the largest private collections in New England, with more than 2900 sheets representing 1535 species, and was donated to NEBC after his death.

Fuller's only published work (Fuller 1899), appeared in the first volume of Rhodora, and presented an astonishingly modern perspective on biological diversity. The paper begins:

> "Like that of most towns in the vicinity of large cities, the flora of Needham is undergoing slow but continual changes, by the introduction of species foreign to its soil, and the extinction of some endemic ones which are so unfortunate as to grow only in the path of settlement. However desirable the increase of population may be in the view of the political economist, some of its accompaniments cause serious mischief for the lover of wild plants ... the extermination of a species from his township by the irresistible wave of improvement leaves a sense of keenest regret."

In this study, I have addressed several questions concerning floristic change. I have attempted to determine if there had been changes in the diversity of native species, of introduced species, and of rare or uncommon native species, and whether changes had occurred disproportionately in some plant groups. I have also attempted to determine if change was related to specific habitats or to the abundance of a particular species, and to examine these floristic changes in light of changes in the landscape.

MATERIALS AND METHODS

The flora at the end of the 20th century was documented through field investigations between June, 2000 and September, 2002. During that period, I investigated plant communities and habitats in Needham on numerous occasions throughout the growing season and identified the plant species occuring at each site. This investigation focused on publicly accessible lands owned by the Town of Needham, the Metropolitan District Commission, and the Trustees of Reservations. Some privately owned lands, with owner permission, were also visited. Voucher specimens were collected when necessary for verification of identification, and are deposited at NEBC. I conducted this survey over three field seasons and did not visit all possible sites in Needham. For these reasons, it is likely that a few taxa have been overlooked and may be discovered in subsequent investigations.

The names of plants in Fuller's manuscript were converted to modern species names by verifying Fuller's spelling in the 5th edition of Gray's *Manual* (Gray 1880), and then updating the names using subsquent editions of Gray's *Manual* and Kartesz (1994). All names used in this study are based on Sorrie and Somers (1999), with author citations standardized using the International Plant Names Index (www.ipni.org/index.html; April 27, 2003). Fuller's specimens at NEBC were examined to verify the 1885 data.

An analysis was conducted to determine if species losses were related to losses of particular habitat types. Species were assigned to one of eight habitat types (open water, fen, emergent marsh, red maple swamp, cultural grassland/wet meadow, white pine/oak woods, rich woods, ruderal) based on personal experience and the published literature (Gleason and Cronquist 1991; Magee and Ahles 1999). Plant community types (described below) were combined for analysis, since species occurred in more than one subtype. The open water habitat type included both open water communities and ponds. The fen habitat included acidic graminoid fen and acidic shrub fen communities. The emergent marsh habitat included deep emergent marsh and shallow emergent marsh communities. The red maple swamp habitat category also included shrub swamp communities. The white pine/oak woods habitat category included the acidic rock outcrop, circumneutral rock outcrop, white pine/oak forest, successional white pine forest, oak forest, and hemlock ravine communities. Each species was assigned to the habitat category in which it was most frequent, although some generalist species were found in more than one habitat.

Species abundance was estimated by the number of localities at which I located each species. Species were classified as rare (one locality), at-risk (two localities), or secure (three or more). This classification did not include estimates of abundance.

Description of the study area. Needham is a suburban community located in the southwestern Boston Metropolitan Area, approximately 16 km southwest of downtown Boston (Figure 1). The town was originally settled in the 1640s, and was originally part of the town of Dedham. Needham was incorporated as a separate town in 1711 (with more than 50 families) and included East Needham and West Needham, which separated as the Town of Wellesley in 1881 (Needham Historical Society 1998). The town currently consists of 32.5 km^2 of land, of which 55.5% (1834 ha) is developed. A small amount of land (74 ha, 2.2%) is still in agricultural use, and 90 ha (2.7%) of the town is open water. The remaining 34.8% (1150 ha) is still open and undeveloped (Needham Open Space Plan, unpubl.). The town had a population of 28,911 in 2000 (U.S. Census). Development was concentrated in the northeast portion of the town, in the commercial/industrial area east of Interstate 95 and in the commercial and residential areas close to the Town Center.

Land use and development changed in the mid-1800s. The railroad was extended to Needham in 1853, when large knitting factories were

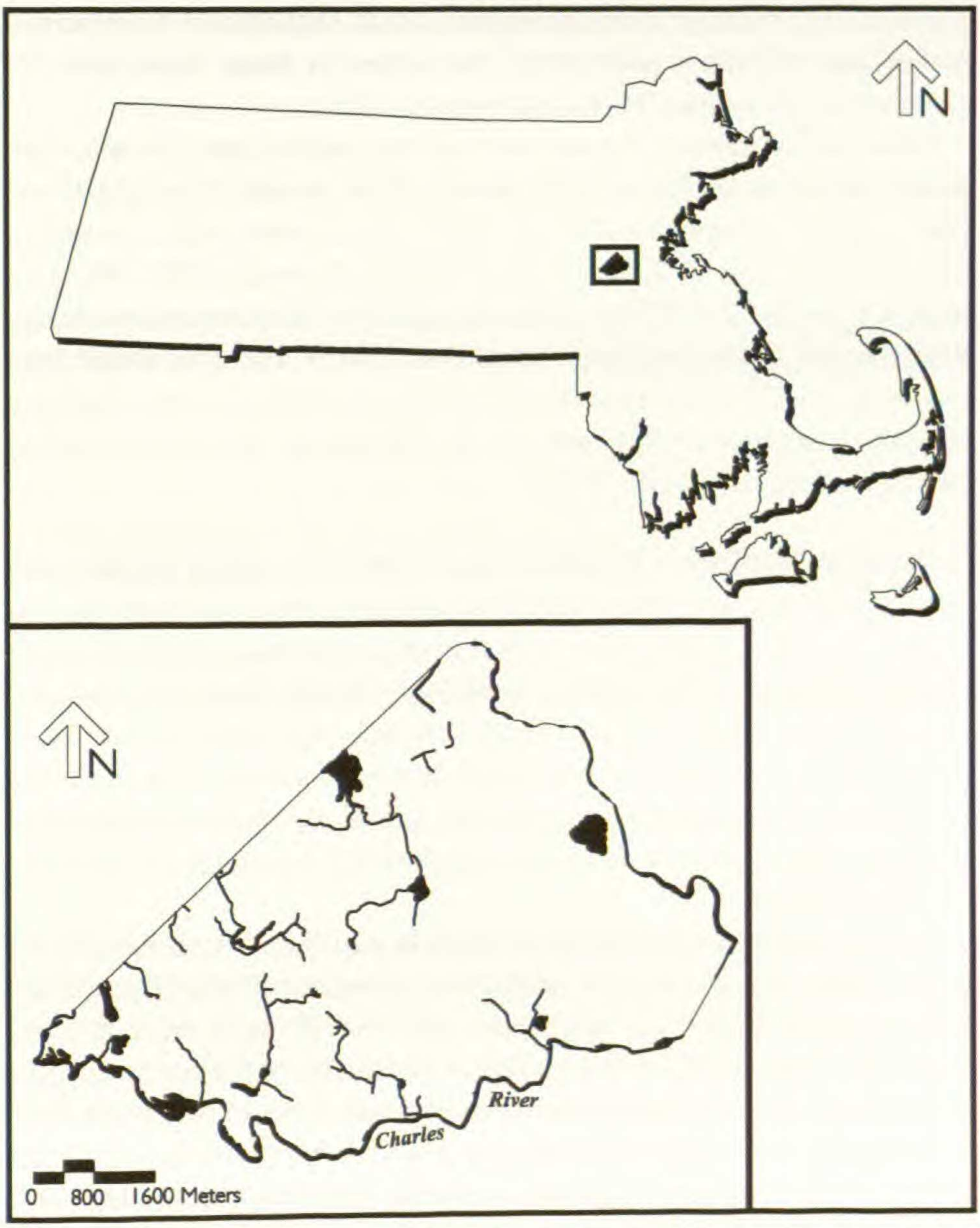

Figure 1. Map of Needham, Massachusetts (adapted from U.S. Geological Survey map).

developed in Highlandville (now Needham Heights). Mills and factories were also located in Charles River Village, Upper Falls, and at the dams of Rosemary Lake and Blacksmith Pond. Farming remained the primary land use in Needham well into the 20th century. Early farmers concentrated on cattle raising and hay. After the establishment of the railroad, Needham also specialized in raising vegetables and flowers. Photographs from the late 1800s show a landscape of rolling pastures

and small forested woodlots throughout much of the town. Commercial flower and seedling production was done in large complexes of greenhouses (Needham Historical Society 1998).

Over the past century, forest cover and agricultural land has been lost. Aerial photogrammetry in 1952 showed 1500 ha (44.1% of the town) with a forest vegetation cover. In 1977, forest cover was estimated to have decreased by 20%, to less than 1200 ha. Current (2001) MassGIS mapping shows 39 (1300 ha) of the land in forest (Needham Open Space Plan, unpubl.). The mapping shows that 67% of the agricultural land remaining in 1952 had been lost by 1977. According to the Needham Historical Society (1998), one of the remaining farms has been in cultivation since the early 1700s.

Physical features. Needham has a generally rolling terrain, with elevations from 30 to 100 m msl. The surficial geology of Needham was shaped by regional glaciation, which resulted in the deposition of till. Glacial features of the current landscape include four drumlins and several eskers. Glacial Lake Charles covered approximately 300 ha in the center of Needham (and extended across several other towns), and left behind a flat deposit of sand and fine gravel. A substantial amount of these deposits were excavated and transported to Boston in the 1860s to fill the Back Bay.

Approximately 75 percent of the boundary of Needham is the Charles River, with 20 km of river shoreline (Needham Open Space Plan, unpubl.). The Charles is impounded by several dams, including the Cochrane Dam (1675) at the historic Charles River Village and Upper Falls Dam. The river generally flows through a broad floodplain with oxbows and old channels. Only one reach, immediately south of the Cochrane Dam, passes through a narrow channel and remains free flowing. All of the surface waters in the town are tributary to the Charles River. These include numerous unnamed intermittent streams as well as three major perennial watercourses, Fuller Brook, Hurd Brook, and Rosemary Brook. Ponds occur as a result of artificial impoundment associated with prior mill and agricultural development. Cutler Pond, a 22 ha waterbody, is adjacent to the Charles River and within the Metropolitan District Commission's (MDC's) Charles River Reservation. Rosemary Lake, a 5.7 ha pond, was built in 1830. Other smaller ponds include the Needham Reservoir, Farley Pond, Walker Pond, and Sabrina Lake. These are small man-made impoundments with partially

developed watersheds, and are consequently shallow and eutrophic. Several small ponds have been lost since the late 1800s. Blacksmith Pond, a shallow impoundment upstream of Rosemary Lake, was drained and filled in the 1930s.

Needham's bedrock geology is largely formed of relatively old volcanic and sedimentary formations (Needham Open Space Plan, unpubl.). The oldest rock formation is the Dedham granodiorite dated to the Precambrian Era. The Mattapan volcanics, Devonian in age, occur in numerous locations. Outcrops of the Roxbury conglomerate, a massive sedimentation formation locally known as "Roxbury puddingstone," were deposited in the late Carbonifereous, and are overlain and interspersed with a more recent basalt known as the Brighton volcanics. These formations, with the exception of the granodiorite, have a circumneutral pH. Outcrops of these rocks are frequent and spectacular in the steep walls and cliffs of Hemlock Gorge, eroded by the Charles River near the northeast border with Newton.

Soils include Hinkley, Windsor, and Merrimac associations in the eastern half of the town and the extreme western part of town. Paxton and Woodbridge associations occur on the hills and drumlins. Hollis association, characteristically containing many bedrock outcrops, occurs throughout the central part of town, and in the extreme northeast corner.

Vegetation. Needham is in the Northeastern Coastal Zone, Boston Basin subunit, dominated by low rolling topography and suburban land uses (Griffith et al. 1994). Plant community types were identified based on the descriptions in Swain and Kearsley (2000), and include rock outcrops, hemlock ravine, various oak-dominated forests, red maple swamp, and several wetland community types, described below.

None of the rich woods communities (mesic hardwood forests on less-acidic or circumneutral substrates) described by Swain and Kearsley (2000) currently occur in Needham.

Acidic Rock Outcrop Community

This is an open community of exposed acid bedrock dominated by mosses and lichens, with herbaceous and woody vegetation in soil pockets, crevices, or around the margins of the outcrop. Characteristic species include *Pinus strobus* L., *Quercus rubra* L., *Q. ilicifolia* Wangenh., *Gaylussacia baccata* (Wangenh.) K. Koch, *Vaccinium angustifolium* Aiton, *Aronia melanocarpa* (Michx.) Fernald, *Schizachy-*

rium scoparium (Michx.) Nash, *Carex pensylvanica* Lam., and *Corydalis sempervirens* (L.) Pers.

Circumneutral Rock Outcrop Community

Like the Acidic Rock Outcrop, this open community of exposed circumneutral bedrock is often dominated by mosses and lichens, with herbaceous and woody vegetation in crevices. Characteristic species include *Juniperus virginiana* L., *Carya* spp., *Carex pensylvanica*, *Danthonia spicata* (L.) P. Beauv. *ex* Roem. & Schult., *Selaginella rupestris* (L.) Spring, *Corydalis sempervirens*, and *Dichanthelium* spp. Some species more characteristic of calcareous rock cliffs (*Asplenium trichomanes*, *Aquilegia canadensis* L., and *Tilia americana* L.) also occur on these outcrops, which typically support small populations of *C. sempervirens*, *Asplenium platyneuron*, *Dryopteris marginalis*, *Dichanthelium linearifolium* (Scribn.) Gould, *Carex rugosperma* Mack., and *Quercus ilicifolia*. *Krigia virginica* (L.) Willd., which occurs on similar rock outcrops in the adjacent town of Wellesley, has not been located in Needham.

Cultural Grassland Community

Grassland communities occur in former pastures dominated by native graminoids (*Carex pensylvanica*, *Danthonia spicata*, and *Schizachyrium scoparium*) or by introduced graminoids (*Anthoxanthum odoratum* L., *Dactylis glomerata* L., *Festuca* spp., *Phleum pratense* L., *Poa* spp.) depending on moisture regime, soil fertility, and past agricultural practices. Forbs [*Asclepias syriaca* L., *Hieraceum* spp., *Nuttallanthus canadensis* (L.) D. A. Sutton, *Rubus* spp., *Solidago* spp.] also are frequent in this community. A subtype of Cultural Grassland not recognized by Swain and Kearsley (2000) occurs in a few locations in Needham. This is a community of dry, sandy or gravelly disturbed sites that occurs along railroad embankments, old railroad yards, and other disturbed sites. This community is dominated by grasses [*Aristida oligantha* Michx., *A. dichotoma* Michx., *Bromus tectorum* L., *Eragrostis spectabilis* (Pursh) Steud., *E. cilianensis* (All.) Lut. *ex* Janch., *Poa compressa* L.], sedges [*Bulbostylis capillaris* (L.) C. B. Clarke *in* Hook., *C. rugosperma* Mack. var. *tonsa* (Fernald) E. G. Voss, *Cyperus lupulinus* (Spreng.) Marcks] and some characteristic forbs [*Hypericum gentianoides* (L.) Britton, Sterns & Poggenb., *Nuttallanthus canadensis*, *Lechea* spp., and *Plantago aristata* Michx.]. *Comptonia peregrina* (L.) Coult. is the most frequent shrub species.

White Pine-Oak Forest Community

These forests of mixed dominance are found on moderately dry moraine or till deposits and are dominated by *Pinus strobus* and *Quercus* species, also including *Betula lenta* L., *Sassafras albidum* (Nutt.) Nees, *Carya* spp., *Castanea dentata* (Marshall) Borkh., *Vaccinium angustifolium*, *Gaylussacia baccata*, and *Viburnum acerifolium* L. Characteristic herbaceous species include *Maianthemum canadense* Desf., *Cypripedium acaule*, *Melampyrum lineare* Desr., *Lysimachia quadrifolia* L., *Gaultheria procumbens* L., *Dennstaedtia punctilobula*, and *Pteridium aquilinum*.

Successional White Pine Forest Community

This is a transitional community of old fields and pastures, dominated by white pine with scattered oaks and red maples. Exotic or weedy shrub and vine species such as *Rhamnus frangula* L., *Lonicera* spp., *Rosa multiflora* Thunb. *ex* Murray, *Celastrus orbiculata* Thunb., and *Toxicodendron radicans* (L.) Kuntze are common. The herbaceous layer is often dominated by *Maianthemum canadense* and *Lycopodium obscurum*. This is the dominant forest community throughout Needham.

Oak Forest Community

Oak forests occupy a broad ecological continuum across a range of mesic to xeric soils. Depending on slope, soil type, fire frequency, and other disturbance factors, these forests may be classified as mixed oak forest, black oak-scarlet oak forest woodland, or oak-hickory forest. These communities have canopies dominated by *Quercus alba* L., *Q. coccinea* Muenschh., *Q. rubra*, and *Q. velutina* Lam., with *Carya* spp., *Betula lenta*, *Acer rubrum* L., *Sassafras albidum*, and *Fraxinus americana* L. The understory and shrub layers are typically dominated by *Ostrya virginiana* (Mill.) K. Koch, *Castanea dentata*, *Hamamelis virginiana* L., *Cornus florida* L., *Corylus* spp., *Viburnum acerifolium*, *Vaccinium angustifolium*, and *Gaylussacia baccata*. The generally sparse herbaceous layer includes *Dennstaedtia punctilobula*, *Maianthemum canadense*, *Carex pensylvanica*, *C. swanii* (Fernald) Mack., *Danthonia spicata*, *Lycopodium obscurum*, and *Cypripedium acaule*.

Hemlock Ravine Community

A hemlock ravine community occurs in Hemlock Gorge, on the rim and north-facing steep slopes and cliffs of the ravine. The community is dominated by *Tsuga canadensis* (L.) Carr with some patches of *Fagus grandifolia* Ehrh. There is little or no shrub or herbaceous layer, although *Epifagus virginiana* (L.) W. P. C. Barton is common under the beech trees and *Dryopteris marginalis* on rock outcrops.

Red Maple Swamp Community

These forested wetland communities are dominated by *Acer rubrum* in the canopy, with occasional *Nyssa sylvatica* Marshall and *Quercus bicolor* Willd. The dense shrub layer contains *Clethra alnifolia* L., *Vaccinium corymbosum* L., *Rhododendron viscosum* (L.) Torr., *Ilex verticillata* (L.) A. Gray, and *Viburnum dentatum* L. The herbaceous layer characteristically contains *Symplocarpus foetidus* (L.) Salisb. *ex* Nutt., *Osmunda cinnamomea*, *O. regalis*, *Thelypteris palustris*, *Rubus hispidus* L., *Carex stricta* Lam., and *Glyceria striata* (Lam.) Hitchc.

Deep Emergent Marsh Community

This is a community dominated by herbaceous species and occurring in shallow permanent water in broad flat areas adjacent to ponds and the Charles River. Characteristic species include *Typha latifolia* L., *T. angustifolia* L., *Phragmites australis* (Cav.) Trin. *ex* Steud., *Scirpus cyperinus* (L.) Kunth, *Carex stricta*, *Calamagrostis canadensis* (Michx.) Beauv., and *Lythrum salicaria* L., with *Decodon verticillatus* (L.) Ell., *Pontederia cordata* L., *Sparganium* spp., *Sagittaria latifolia* Willd., and *Peltandra virginica* (L.) Schott *ex* Schott & Endl. along the edge of open water.

Shallow Emergent Marsh Community

This community is similar to the deep emergent marsh, but with water depths only seasonally above the surface of the substrate. Dominant species include *Carex stricta*, *Calamagrostis canadensis*, *Phalaris arundinacea* L., and *Lythrum salicaria*. The diverse community often also includes *Carex stipata* Muhl. *ex* Willd., *C. vulpinoidea* Michx., *Carex* spp., *Juncus* spp., and *Thelypteris palustris*. Shallow emergent marshes occur in extensive areas along the Charles River, where they are dominated by *P. arundinacea*. *Cornus amomum* Mill., *Urtica dioica* L., *Acer rubrum*, *Hibiscus moscheutos* L., and *Cephalanthus occidentalis* L. occur in higher hummocks within this marsh system.

Wet Meadow Community

Wet meadow communities are similar to the shallow emergent marsh, but soils are seasonally saturated and rarely inundated. Dominant species include a wide range of *Carex* species [*C. stricta*, *C. lacustris* Willd., *C. stipata*, *C. vulpinoidea*, *C. annectens* (E. P. Bicknell) E. P. Bicknell, *C. vesicaria* L.], *Calamagrostis canadensis*, *Polygonum* spp., *Scirpus cyperinus*, *Juncus effusus* L., *Glyceria canadensis* (Michx.) Trin., *Poa palustris* L., *Thalictrum pubescens* Pursh, *Aster umbellatus* Mill., *Eupatorium dubium* Willd. *ex* Poir., *Onoclea sensibilis*, and *Thelypteris palustris*.

Shrub Swamp Community

This is represented by a group of communities with permanently or seasonally saturated soils, often at the transition between emergent marshes and swamp forests, and likely to be a successional stage in the transition from wet meadow to forested wetland. Shrub swamps are dominated by *Alnus serrulata* (Aiton) Willd., *Cornus amomum*, *Ilex verticillata*, *Salix* spp., *Spiraea alba* Du Roi, *S. tomentosa* L., *Vaccinium corymbosum*, *Viburnum dentatum*, and *Acer rubrum* saplings. Herbaceous species typical of swamps or wet meadows may also occur.

Acidic Graminoid Fen Community

This is an acidic peatland community dominated by sedges and sphagnum, including *Carex comosa* Boott, *C. lupulina* Muhl. *ex* Willd., *Rhynchospora capitellata* (Michx.) Vahl, and *Vaccinium macrocarpon* Aiton. It has a sparse shrub and tree stratum that may include *Acer rubrum*, *Toxicodendron vernix* (L.) Kuntze, *Rhododendron viscosum*, and *V. corymbosum*. *Nuphar variegata* Durand *ex* Clinton, and *Nymphaea odorata* Aiton occur in deeper pools.

Acidic Shrub Fen Community

This community is similar to the graminoid fen, but dominated by shrubs and spagnum. Dominant species include *Decodon verticillatus*, *Chamaedaphne calyculata* (L.) Moench, *Spiraea tomentosa*, *Triadenum virginicum* (L.) Raf., and *Woodwardia virginica*.

Open Water Community

In Needham this community type occurs in the shallow ponds and the Charles River. Characteristic species of the Charles River impoundments include *Nuphar variegata*, *Nymphaea odorata*, *Cabomba caroliniana* A. Gray, *Lemna minor* L., *Wolffia* spp., *Potamogeton epihydrus* Raf., *P. robbinsii* Oakes, *P. spirillus* Tuck., *P. natans* L., *P. crispus* L., *Vallisneria americana* Michx., *Marsilea quadrifolia* L., *Myriophyllum spicatum* L., *Polygonum amphibium* L., and *Ceratophyllum demersum* L. *Utricularia macrorhiza* LeConte occurs in a few locations. *Decodon verticillatus*, *Peltandra virginica*, *Pontederia cordata*, and *Sparganium androcladum* (Engelm.) Morong occur on the river shores. Water levels in these impoundments do not fluctuate greatly, and there are no seasonally exposed mud banks that would provide habitat for annual species.

Pond species include submerged and floating aquatics, typically *Nuphar variegata*, *Nymphaea odorata*, *Egeria densa* Planch., *Elodea*

Table 1. Comparison of 1885 and 2002 floristic composition of Needham, Mass.

	Number of Species		
	Native	Introduced	Total
Year			
1885	563	128	691
2002	427	201	628
Comparison			
Species Common to Both	318	87	405
Species Lost	245	42	287
New Species	107	115	222

canadensis Michx., *Callitriche palustris* L., *Lemna minor*, *Wolffia brasiliensis*., *Potamogeton epihydrus*, and *P. pusillus* L.

RESULTS

In 1885, Fuller recorded 691 species of vascular plants in Needham (Fuller, unpubl. ms.). Of these, 563 were native to New England, and 128 (18.5%) were introduced (Table 1). Species present represented 117 families, 42 species of trees, 36 species of ferns and lycopods, and 12 species of orchids. The largest families were the Asteraceae (75 species), Poaceae (62 species), and Cyperaceae (59 species). In 2000–2002, I recorded 628 species, of which 427 were native and 201 (32%) were introduced. There were 114 families, 57 species of trees, 23 ferns, and 3 species of orchids. The largest families were the Poaceae (70 species), Asteraceae (64), and Cyperaceae (55). Twenty-six species (7 native, 19 exotic) were not previously reported in Norfolk County (Sorrie and Somers 1999; Table 2). In combination, the two surveys included 914 species of vascular plants. The complete lists are available from the NEBC archives, the Harvard University Herbaria library, and the author.

The actual floristic change was determined on a species-by-species comparison of species lost and gained. This analysis demonstrated that 405 species found in 1885 were still present in 2000–2002 (Table 1). Of the native species, 245 (43.5%) found in 1885 have been lost, while 107 native species not found in 1885 have been gained. Of the introduced species, 42 species (primarily agricultural weeds) have been lost, and 115 species have been gained. Only 64.5% of the flora of 1885 was still present at the end of the 20th century.

Table 2. Species new to Norfolk County, 2000–2002.

Family	Species
Asteraceae	*Aster cordifolius* L.
	Aster puniceus L.
	Eupatorium maculatum L.
	Silphium perfoliatum L.
Buxaceae	*Pachysandra terminalis* Siebold & Zucc.
Caprifoliaceae	*Lonicera japonica* Thunb.
Caryophyllaceae	*Cerastium semidecandrum* L.
	Silene japonica (Sw.) Ohwi
Celastraceae	*Euonymus alata* (Thunb.) Siebold
	Euonymus fortunei (Turcz.) Hand.-Mazz.
Cyperaceae	*Carex hirta* L.
Elaeagnaceae	*Elaeagnus umbellata* Thunb.
Fabaceae	*Lotus corniculatus* L.
Hydrangeaceae	*Hydrangea paniculata* Siebold
Lemnaceae	*Wolffia brasiliensis* Wedd.
	Wolffia columbiana H. Karst.
Orchidaceae	*Epipactis helleborine* (L.) Crantz
Papaveraceae	*Macleaya cordata* (Willd.) R. Br.
Poaceae	*Agrostis hyemalis* (Walter) Britton, Sterns & Poggenb.
	Eleusine indica (L.) Gaertn.
Rutaceae	*Phellodendron japonicum* Maxim.
Salicaceae	*Populus deltoides* W. Bartram *ex* Marshall
Scrophulariaceae	*Digitalis purpurea* L.
Solanaceae	*Solanum nigrum* L.
Tiliaceae	*Tilia cordata* Mill.
Vitaceae	*Parthenocissus tricuspidata* (Siebold & Zucc.) Planch.

Taxonomic groups. There has been turnover at the family level as well as at the species level. Twelve families present in 1885 were no longer extant at the time of this study. These include the Ophioglossaceae (5 species), Saxifragaceae (3 species), Isoetaceae, Linaceae, and Menyanthaceae (2 species). The Acoraceae, Adiantaceae, Melastomataceae, Portulacaceae, Sarraceniaceae, Staphyleaceae, and Xyridaceae, each with a single species, were also extirpated. Seventy-three genera have been lost (Table 3). Most of these were represented by a single species, although several genera once present with multiple species have been lost (*Actaea*, *Saxifraga*, *Pycnanthemum*, *Isoetes*, *Myrica*, *Botrychium*, *Platanthera*, *Spiranthes*, *Linum*, *Eriophorum*). Other genera, although persisting, have lost a substantial number of the species present in 1885: *Pyrola*, 2 of 3; *Rynchospora*, 2 of 3; *Thalictrum*, 2 of 3; *Viola*, 5 of 8. Although none of the 5 species of *Desmodium* present in 1885 were extant in 2000–2002, other native *Desmodium* species were found in Needham.

Table 3. Genera of native vascular plants extirpated from Needham, Mass.

Family	Genus	Number of Species Lost
Acoraceae	*Acorus*	1
Adiantaceae	*Adiantum*	1
Apiaceae	*Conioselinum*	1
	Sanicula	1
Araliaceae	*Panax*	1
Asteraceae	*Krigia*	1
	Xanthium	1
Brassicaceae	*Cardamine*	1
Cabombaceae	*Brasenia*	1
Campanulaceae	*Triodanis*	1
Caprifoliaceae	*Triosteum*	1
Caryophyllaceae	*Paronychia*	1
Crassulaceae	*Penthorum*	1
Cupressaceae	*Chamaecyparis*	1
Cyperaceae	*Eriophorum*	3
	Fimbristylis	1
Dryopteridaceae	*Cystopteris*	1
	Deparia	1
	Gymnocarpium	1
	Polystichum	1
	Woodsia	1
Ericaceae	*Andromeda*	1
	Epigaea	1
Fabaceae	*Tephrosia*	1
Gentianaceae	*Gentiana*	1
	Gentianopsis	1
Iridaceae	*Sisyrinchium*	1
Isoetaceae	*Isoetes*	2
Juglandaceae	*Juglans*	1
Lamiaceae	*Hedeoma*	1
	Pycnanthemum	2
	Stachys	1
Liliaceae	*Aletris*	1
	Clintonia	1
Linaceae	*Linum*	1
Lycopodiaceae	*Huperzia*	1
	Lycopodiella	1
Melastomataceae	*Rhexia*	1
Menyanthaceae	*Menyanthes*	1
	Nymphoides	1
Myricaceae	*Myrica*	2
Ophioglossaceae	*Botrychium*	4
	Ophioglossum	1
Orchidaceae	*Arethusa*	1
	Calopogon	1
	Coeloglossum	1

Table 3. Continued.

Family	Genus	Number of Species Lost
	Corallorrhiza	1
	Liparis	1
	Platanthera	3
	Pogonia	1
	Spiranthes	2
Orobanchaceae	*Orobanche*	1
Pinaceae	*Larix*	1
Platanaceae	*Platanus*	1
Poaceae	*Andropogon*	1
	Elymus	1
	Sorghastrum	1
	Zizania	1
Portulacaceae	*Portulaca*	1
Pyrolaceae	*Orthilia*	1
Ranunculaceae	*Actaea*	2
	Hepatica	1
Rutaceae	*Zanthoxylum*	1
Sarraceniaceae	*Sarracenia*	1
Saxifragaceae	*Chrysosplenium*	1
	Saxifraga	2
Scrophulariaceae	*Castilleja*	1
	Lindernia	1
	Pedicularis	1
	Penstemon	1
Staphyleaceae	*Staphylea*	1
Thelypteridaceae	*Phegopteris*	1
Urticaceae	*Pilea*	1
Xyridaceae	*Xyris*	1

Ferns and orchids are the two taxonomic groups that have lost the largest proportion of species. Twenty-one species of ferns and other cryptogamic groups (Isoetaceae, Equisetaceae, Selaginellaceae, Lycopodiacae) were no longer found in Needham, a loss of 50% of the original fern flora (Table 4). Eight genera and 11 of the 13 historical species of orchids—85% of the historical orchid flora—have been lost (Table 5). Only two native species (*Cypripedium acaule* and *Goodyera pubescens*) remained, along with the introduced *Epipactis helleborine*. Oddly, although Brown and Folsom (1997) cited Cutler Park in Needham as a site that often had good orchid populations, I found no orchids there other than the three extant species. Substantial losses (49% of the original 59 species) have also occurred in the Cyperaceae.

Table 4. Status of ferns and fern allies in Needham, Mass. X = present in flora.

Family	Species	Year	
		1885	2002
Adiantaceae	*Adiantum pedatum* L.	X	
Aspleniaceae	*Asplenium platyneuron* (L.) Britton, Sterns & Poggenb.	X	X
	Asplenium rhizophyllum L.	X	
	Asplenium trichomanes L.	X	X
Blechnaceae	*Woodwardia virginica* (L.) Sm.	X	X
Dennstaedtiaceae	*Dennstaedtia punctilobula* (Michx.) T. Moore	X	X
	Pteridium aquilinum (L.) Kuhn	X	X
Dryopteridaceae	*Athyrium filix-femina* (L.) Roth	X	X
	Cystopteris fragilis (L.) Bernh.	X	
	Deparia acrostichoides (Sw.) M. Kato	X	
	Dryopteris carthusiana (Vill.) H. P. Fuchs		X
	Dryopteris cristata (L.) A. Gray	X	X
	Dryopteris marginalis (Linn.) A. Gray	X	X
	Gymnocarpium dryopteris (L.) Newman	X	
	Matteuccia struthiopteris (L.) Tod.		X
	Onoclea sensibilis L.	X	X
	Polystichum acrostichoides (Michx.) Schott	X	
	Woodsia obtusa (Spreng.) Torr.	X	
Equisetaceae	*Equisetum arvense* L.	X	X
	Equisetum fluviatile L.	X	
	Equisetum hyemale L.	X	
	Equisetum sylvaticum L.	X	
Isoetaceae	*Isoetes echinospora* Durieu	X	
	Isoetes engelmannii A. Braun	X	
Lycopodiaceae	*Diphasiastrum digitatum* (Dill. *ex* A. Braun) Holub	X	X
	Huperzia lucidula (Michx.) Trevis.	X	
	Lycopodiella appressa (Chapm.) Cranfill	X	
	Lycopodium clavatum L.	X	X
	Lycopodium obscurum L.	X	X
Ophioglossaceae	*Botrychium dissectum* Spreng.	X	
	Botrychium lanceolatum (Gmelin) Ångstr.	X	
	Botrychium matricariifolium (Döll) A. Braun *ex* W. D. J. Koch	X	
	Botrychium virginianum (L.) Sw.	X	
	Ophioglossum pusillum Raf.	X	
Osmundaceae	*Osmunda cinnamomea* L.	X	X
	Osmunda claytoniana L.	X	X
	Osmunda regalis L.	X	X
Polypodiaceae	*Polypodium virginianum* L.	X	X
Selaginellaceae	*Selaginella apoda* (L.) Spring	X	
	Selaginella rupestris (L.) Spring	X	X
Thelypteridaceae	*Phegopteris hexagonoptera* (Michx.) Fée	X	
	Thelypteris noveboracensis (L.) Nieuwl.	X	X
	Thelypteris palustris Schott	X	X
	Thelypteris simulata (Davenp.) Nieuwl.		X

Table 5. Status of orchids in Needham, Mass. X = present in flora.

Species	Year	
	1885	2002
Arethusa bulbosa L.	X	
Calopogontuberosus(L.)Britton, Sterns & Poggenb.	X	
Coeloglossum viride (L.) Hartm.	X	
Corallorrhiza maculata (Raf.) Raf.	X	
Cypripedium acaule Aiton	X	X
Epipactis helleborine (L.) Crantz		X
Goodyera pubescens (Willd.) R. Br.	X	X
Liparis loeselii (L.) Rich.	X	
Platanthera clavellata (Michx.) Luer	X	
Platanthera lacera (Michx.) G. Don	X	
Platanthera psychodes (L.) Lindl.	X	
Pogonia ophioglossoides (L.) Ker Gawl.	X	
Spiranthes cernua (L.) Rich.	X	
Spiranthes lacera (Raf.) Raf.	X	

The loss of native tree species was relatively small. Tree species lost since 1885 include *Chamaecyparis thyoides* (L.) Britton, Sterns & Poggenb., *Larix laricina* (Du Roi) Koch, *Picea mariana* (Mill.) Britton, Sterns & Poggenb., *Castanea dentata*, *Juglans cinerea* L., and *Platanus occidentalis* L. The tree species found in 2000–2002 but not present in 1885 are primarily introduced, although it is interesting to note that Fuller did not report *Betula populifolia* Marshall, a species now common.

Habitat analysis. Losses of native species were distributed across all habitats (Table 6), with the highest numbers and percentages of lost species occurring in the grassland habitat (58 species, 23.6%) and the rich woods habitat (55 species, 22.4%).

Species of wet and dry fields and pastures have largely disappeared from Needham. These include several *Aster* spp., *Cirsium muticum* Michx., *Carex conoidea* Schkuhr *ex* Willd., *Gentiana andrewsii* Griseb., *Gentianopsis crinita* (Froel.) Ma, *Sisyrinchium angustifolium* Mill., *Pycnanthemum muticum* (Michx.) Pers., *Aletris farinosa* L., *Lilium philadelphicum* L., *Ophioglossum pusillum*, *Platanthera lacera*, *Tridens flavus* (L.) Hitchc., *Polygala cruciata* L., *Rosa caroliniana* L., *Penstemon hirsutus* (L.) Willd., *Selaginella apoda*, *Andropogon gerardii* Vitman, *Sorghastrum nutans* (L.) Nash, and *Xyris torta* Small.

Most of the obligate fen or bog species, including *Chamaecyparis thyoides*, *Larix laricina*, *Picea mariana*, *Myrica gale* L., *Sarracenia*

Table 6. Loss of native plant species by habitat.

Habitat	Number of Native Species	Percent Extirpated (%)
Open Water	17	6.9
Acidic Fen	27	11.0
Emergent Marsh	22	9.1
Red Maple Swamp	22	8.9
Cultural Grassland/Wet Meadow	58	23.6
White Pine/Oak Woods	38	15.5
Rich Woods	55	22.4
Ruderal, disturbed, agricultural	6	2.4
TOTAL	245	100

purpurea L., *Pogonia ophioglossoides Arethusa bulbosa*, *Calopogon tuberosus*, *Menyanthes trifolia* L., *Nymphoides cordata* (Ell.) Fernald, *Eriophorum* spp., *Carex livida* (Wahlenb.) Willd., *C. sterilis* Willd., *Drosera intermedia* Hayne, and *Utricularia inflata* Walter (probably *U. radiata* Small), have been lost, indicating that many fen and bog habitats have disappeared. Some species of other wetland habitats have also been lost, including *Gratiola aurea* Pursh, *Euthamia tenuifolia* (Pursh) Nutt., and *Xyris torta*, all species typical of coastal-plain pondshores or of other pondshores that slope very gradually and are seasonally exposed. *Zizania aquatica* L. has also vanished from the Charles River in Needham.

Most of the rich woods species and species of calcareous rock outcrops [*Staphylea trifolia* L., *Adiantum pedatum*, *Botrychium* spp., *Solidago flexicaulis* L., *Triosteum perfoliatum* L., *Cornus rugosa* Lam., *Carex sparganioides* Muhl. *ex* Willd., *Gymnopcarpium dryopteris*, *Allium canadense* L., *Actaea* spp., *Thalictrum thalictroides* (L.) Eames & B. Boivin, *Geum rivale* L., *Viola pubescens* Aiton, and *Celastrus scandens* L.] also are no longer present.

Invasive exotic species now recognized as significant threats to native communities have been introduced after 1885: *Acer platanoides* L., *A. pseudoplatanus* L., *Ailanthus altissima* (Mill.) Swingle, *Alliaria petiolata* (Bieb.) Cavara & Grande, *Berberis thunbergii* DC., *Cabomba caroliniana*, *Celastrus orbiculata*, *Elaeagnus umbellata*, *Euonymus* spp., *Iris pseudacorus* L., *Lonicera japonica*, *L. morrowii* A. Gray, *Lythrum salicaria*, *Myriophyllum spicatum*, *Phalaris arundinacea*, *Phragmites australis*, *Rhamnus frangula*, and *Rosa multiflora*. *Acer platanoides*, *Lonicera* spp., *C. orbiculata*, *Euonymus alata*, *R. multiflora*, and *Rhamnus frangula* are present at virtually all upland sites regardless of the apparent level of disturbance. *Ailanthus*, *Alliaria*, and

Elaeagnus are characteristic of roadsides and ruderal sites, while the meadows along the Charles River are dominated by *Lythrum salicaria* and *Phalaris arundinacea*. *Wolffia brasiliensis* appears to have replaced *W. columbiana* along the Charles River and in other water bodies. Other exotic species well established in Needham, particularly *Hieraceum sabaudum* L., are not recognized as invasives (Mehrhoff et al. 2003; Randall 1998; Virginia Department of Conservation and Recreation 2003).

Rare species. In 1885, 33 species currently on the Massachusetts List of Endangered and Threatened Species occurred in Needham. None of these species are currently extant. One is now considered Historic [*Castilleja coccinea* (L.) Spreng.]. Seven of these are now listed as Endangered [*Sagittaria subulata* (L.) Buchenau, *Gentiana andrewsii*, *Triosteum perfoliatum*, *Carex livida*, *Galium boreale* L., *Penstemon hirsutus*, and *Viola adunca* Sm.]. Nine are listed as Threatened [*Asclepias purpurascens* L., *Lobelia siphilitica* L., *Carex oligosperma* Michx., *C. sterilis*, *Eriophorum gracile* W. D. J. Koch, *Ophioglossum pusillum*, *Arethusa bulbosa*, *Aristida purpurascens* Poir., and *Sphenopholis pensylvanica* (L.) Hitchc.]. One species is considered of Special Concern [*Conioselinum chinense* (L.) Britton, Sterns & Poggenb.], and 15 are not state-protected but are on the Watch List [*Aster radula* Aiton, *Prenanthes alba* L., *Silene caroliniana* Walter, *Lechea minor* L., *Acalypha virginica* L., *Desmodium cuspidatum* (Muhl. *ex* Willd.) DC. *ex* Loudon, *Lespedeza violacea* (L.) Pers., *Juglans cinerea*, *Utricularia inflata*, *Botrychium lanceolatum*, *B. matricariifolium*, *Coeloglossum viride*, *Polygala verticillata* L., *Ranunculus fascicularis* Muhl. *ex* Bigelow, and *Sparganium angustifolium* Michx.]. Five Watch List species were documented to occur in Needham during this study, one introduced [*Sporobolus compositus* (Poir.) Merr.], and four native (*Carex haydenii* Dewey, *Salix pedicillaris* L., *U. minor* L., and *Wolffia brasiliensis*).

The Massachusetts Natural Heritage and Endangered Species Program (2002) lists 10 state-listed species documented to occur in Needham: *Houstonia longifolia* Gaertn. var. *longifolia*, *Liatris scariosa* (L.) Willd. var. *novae-angliae* Lunell, *Platanthera flava* (L.) Lindl. var. *herbiola* (R. Br.) Luer, *Prenanthes serpentaria* Pursh, *Scirpus longii* Fernald, *Sphenopholis nitida* (Biehler) Scribn., *S. pensylvanica*, *Spiranthes vernalis* Engelm. & A. Gray, *Trisetum spicatum* (L.) Richt., and *Viola brittoniana* Pollard. None of these species were located during the 2000–2002 survey, although *Scirpus longii* and *V. brittoniana* are

likely to be present (T. Rawinski, Massachusetts Audubon Society Regional Ecologist, pers. com.).

Fuller (1899) reported that several species, present in 1880, had been lost to development: *Hottonia inflata* Ell., *Polygonella articulata* (L.) Meisn., *Crotalaria sagittalis* L., *Castilleja coccinea*, and *Aletris farinosa*. He listed others that were present in only one site and at risk from extirpation "by what has been termed, not inaptly from our point of view, 'the shabby tide of progress'": *Staphylea trifolia*, *Conioselinum canadense*, *Lonicera villosa* (Michx.) Schult., *Euthamia tenuifolia*, *Andromeda polifolia* L., *Liparis loeselii* (L.) Rich., *Maianthemum trifolium* (L.) Sloboda, *Trisetum spicatum*, *Sphenopholis pensylvanica*, and *Asplenium rhizophyllum*. None of these species were present in 2002.

Species abundance. The native species present in 2002 were categorized by frequency to estimate potential future turnover. Those native species thought to have been planted (*Betula papyrifera*, *Sanguinaria canadensis*) were excluded from the analysis. Over half of the native species (240, or 56.5%) occurred in three or more localities, and are considered to be secure. Some species (58, or 13.7%) occurred in two localities, and 127 native species (29.9%) were found in only a single locality. Species that occurred in one or two localities are considered at risk of loss, and constitute 43.5% of the native flora extant in 2000–2002. Since Fuller did not provide estimates of abundance in his checklist, it is not possible to compare present and historical frequency or abundance.

DISCUSSION

The number of species recorded in Needham (914 taxa in total; 628 extant) is comparable to the results of other studies in New England. Eaton (1974) reported 1151 species in Concord, Massachusetts, a town of comparable size, land use history, and proximity to Boston. Holland and Sorrie (1989) recorded 243 species on a substantially smaller, 17.4 ha area in New Hampshire. Blake (1964) reported 898 species and 113 families in Stoughton, Massachusetts, also comparable to Needham, but Blake's data were collected in 1908–1929, and do not necessarily reflect the current biodiversity. Bertin (2000) recorded 988 species in Worcester, Massachusetts, in an area three times the size of Needham. Weatherbee (1996) reported 1222 taxa of native species and 433 introduced species in Berkshire County, Massachusetts, an area of 2434 square kilometers.

The current percent of introduced species (32%), and the change in the diversity and contribution of alien species over time (118 new species since 1885, when introduced species made up 18.67% of the flora), is also comparable to other studies. Sorrie and Somers (1999) reported that 39% of the Massachusetts flora consists of introduced species, while Bertin (2000) reported 34% in Worcester. Robinson et al. (1994) recorded 33.5% alien species on Long Island, New York, an increase of 100 species from 1930 (26.8%). Weatherbee (1996) reported 27% introduced species in Berkshire County, an increase of 107 species from 1922, when aliens composed 17% of the flora. Drayton and Primack (1996) reported that exotic species increased in abundance from 17% of the flora of the Middlesex Fells to 26% between 1894 and 1993. Eaton (1974) reported that 25% of the species of Concord were exotic.

The pattern of change in native species is similar to other studies, although the percentage of native species lost (44%) is substantially higher than at other locations in New England. In Needham, I documented that 428 of the original native species have been lost, while 109 new native species have been gained. Bertin (2002) found a loss of 18.4% (147 species) of the original flora. Holland and Sorrie (1989) found 27% of native species had been lost since 1911, and documented a turnover of 64 species lost and 57 species gained in what they termed "a continuum of small changes." Drayton and Primack (1996) found that 38% of the flora of the Middlesex Fells, a 400 ha preserve in the suburban Boston area, had been lost in 100 years. This estimate, however, excluded the Cyperaceae, Poaceae, Juncaceae, aquatic families, ferns, and other cryptogams. Weatherbee (1996) documented a loss of only 9.7% (128 species) of the original native flora, with a gain of 35 new species. Robinson et al. (1994) showed the most similar pattern in species change to that of Needham, with a loss of 40.9% of the native flora of Long Island since 1930.

I found some correlation between species loss and habitat loss, with the highest losses (22–24%) of species characteristic of grassland habitats and rich woods. The rich woods community type no longer occurs in Needham. Bertin (2002) did not find higher than average losses for grasslands species, but found the greatest percent of species losses (up to 25%) in bogs, calcareous terrestrial habitats, aquatic habitats, and coniferous forests. Similarly, Drayton and Primack (1996) found the greatest losses of species in open moist habitats. Overlease (1987) described the changes in plant communities in Chester County, Pennsylvania over 150 years, as well as the effects on plant composition. He found similar patterns, particularly in wet meadows and marshes,

where invasive species such as *Lythrum salicaria* had become dominant and native species, including *Gentiana andrewsii*, *Gentianopsis crinita*, and *Castilleja coccinea* were extirpated or rare. Robinson et al. (1994) found no correlation between species loss and habitat type, and documented a 40–45% loss of species in all habitat types.

Losses of taxonomic diversity at the generic and family levels in Needham were substantially lower than for Long Island (Robinson et al. 1994) where 46 of the 133 families (35%) and 197 of the 433 native genera (45%) have been lost since 1930. The Long Island study showed that the highest losses were to the group of herbaceous perennials (45%) and the lowest losses to the trees, similar to the results for Needham. Bertin (2002) found the highest losses of species within the same families as in Needham (Menyanthaceae, Ophioglossaceae, Lentibulariaceae, Orchidaceae), although these families still persist in Worcester. Bertin (2002) found also that half of the orchid species in Worcester had been extirpated, and cited numerous studies that have shown the same general pattern that losses of orchids were greater than the overall species loss. Drayton and Primack (1996) documented that 7 of the historical 9 orchid species in the Middlesex Fells had been extirpated. Lamont et al. (1988) found that 40% of the orchids of Long Island (14 of 35 species) had been lost, and that most of the remaining species were known from fewer than 10 populations. *Cypripedium acaule* and *Goodyera pubescens*, the only native orchids remaining in Needham and the Middlesex Fells (Drayton and Primack 1996), were among the most common orchid species remaining on Long Island.

The loss of rare and uncommon taxa in Needham is also similar to patterns observed elsewhere (Bertin 2002). Robinson et al. (1994) showed that uncommon plants and plants of conservation concern had been lost at a higher percentage than common species, and found that overall abundance was the one variable tested that was significantly correlated with the persistence of a species.

Why have so many species vanished? There are likely to have been multiple causes of species loss, which cumulatively have reduced the native flora of Needham by 44%. Habitat loss and habitat change appear to be the two most important factors. Development has undoubtedly resulted in the loss of habitat. As discussed above, agricultural fields, pastures and grasslands, and rich woods have largely disappeared from Needham. This agricultural land may have protected a diversity of habitats, including woodlots, wetlands, and hedgerows as well as pastures (Robinson et al. 1994) and may have made a significant

contribution to overall plant species diversity. Although large tracts of oak woods communities remain in Needham, much of this habitat has also been developed, which may have resulted in the loss of some species with small population sizes or limited distributions. Some water bodies, notably Blacksmith Pond, reported by Fuller to have populations of *Isoetes engelmannii* and *Nymphoides cordata* (Ell.) Fernald, were drained and filled in the early 20th century.

Changes in habitat due to succession are also likely to have resulted in floristic change. O'Keefe and Foster (1998) noted that the peak of deforestation in Massachusetts occurred around 1860, when 70% of the land was cleared. With the decline in agriculture in the second half of the 19th century, forests rebounded in most of the state. Fuller (1895 unpubl. ms.) sampled this transitional period between the peak of agriculture and the recovery of forest, although expansion of the Boston suburbs was also beginning to affect land use. When abandoned as pastures, wet meadows and fens develop into shrub swamp and red maple swamp wetlands. Upland fields and pastures develop into successional white pine-oak forest. Both examples of natural community change result in the loss of plant species adapted to open communities.

Other factors may also contribute to the loss of species. Epidemic diseases have resulted in the loss of *Castanea dentata* (as a tree, although it is still present as a shrub or short-lived sapling) and *Juglans cinerea*. Invasive species are also likely to have resulted in floristic change, although this is not well documented in the literature. Many meadows along the Charles River, formerly containing diverse communities of grasses, rushes, sedges and orchids, today are dominated by *Lythrum salicaria* or by dense monodominant stands of *Phalaris arundinacea*. Neither species was present in 1885. The effects of introduction of *Rhamnus frangula*, *Rosa multiflora*, or *Celastrus orbiculata* on native plant communities are not known. Gundale (2002) has suggested that certain exotic earthworms (*Lumbricus rubellus*) reduce the depth of the organic horizon which the mycoheterotrophic gametophytes of *Botrychium mormo* W. H. Wagner and other *Botrychium* species require, and that the removal of the organic horizon has lead to the local extirpation of *B. mormo*. This factor may account for the extirpation of *Botrychium* species in Needham, and may also affect the distribution of mycotrophic orchid species.

The risk of loss of species in the future is due to factors of development (anthropogenic habitat loss), random stochastic events, and habitat change due to succession, invasive species, or management. Species loss due to development is likely to be low, as the majority of remaining undeveloped

locations are in conservation ownership (Metropolitan District Commission, Trustees of Reservations, Town of Needham Conservation, or Town Forest lands). However, town-owned lands not dedicated to conservation or parkland could be converted to other uses such as schools or low-income housing. Wetland habitats are protected from development by stringent state and local wetlands protection laws, and by the extensive areas in the Army Corps of Engineers Natural Valley Storage program. Minor changes in management of public lands can affect populations; during this study, the number of populations of *Ceanothus americanus* L. was reduced from two to one as a result of cemetery expansion. Several at-risk species [*Desmodium nudiflorum* (L.) DC., *D. paniculatum* (L.) DC., *Bartonia virginica* (L.) Britton, Sterns & Poggenb., *Carex cumulata* (L. H. Bailey) Mack., and *C. vesicaria*] occur in relatively small populations and are restricted to the grassland community over a natural gas pipeline. If the pipeline needed to be replaced, excavation and construction could result in the loss of these species.

The continued expansion of invasive species and their increasing dominance in many communities could also result in the loss of native species. As demonstrated by numerous researchers, small populations are vulnerable to stochastic change, decrease in size, and localized extinctions. These effects may be offset if there are "source" populations close enough to allow recolonization of suitable habitat, and if habitat fragmentation does not prevent seed dispersal between habitats. However, for many of the at-risk species in Needham, such as *Drosera rotundifolia* L. and *Utricularia minor*, there are not likely to be large source populations within dispersal distance due to their specialized habitat requirements and the degree of development of the surrounding communities. These factors create the potential that, in the next century, researchers may find that the diversity of native vascular plants has declined by a further 43%.

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